SPECIAL CIRCULAR 101 JANUARY 1977

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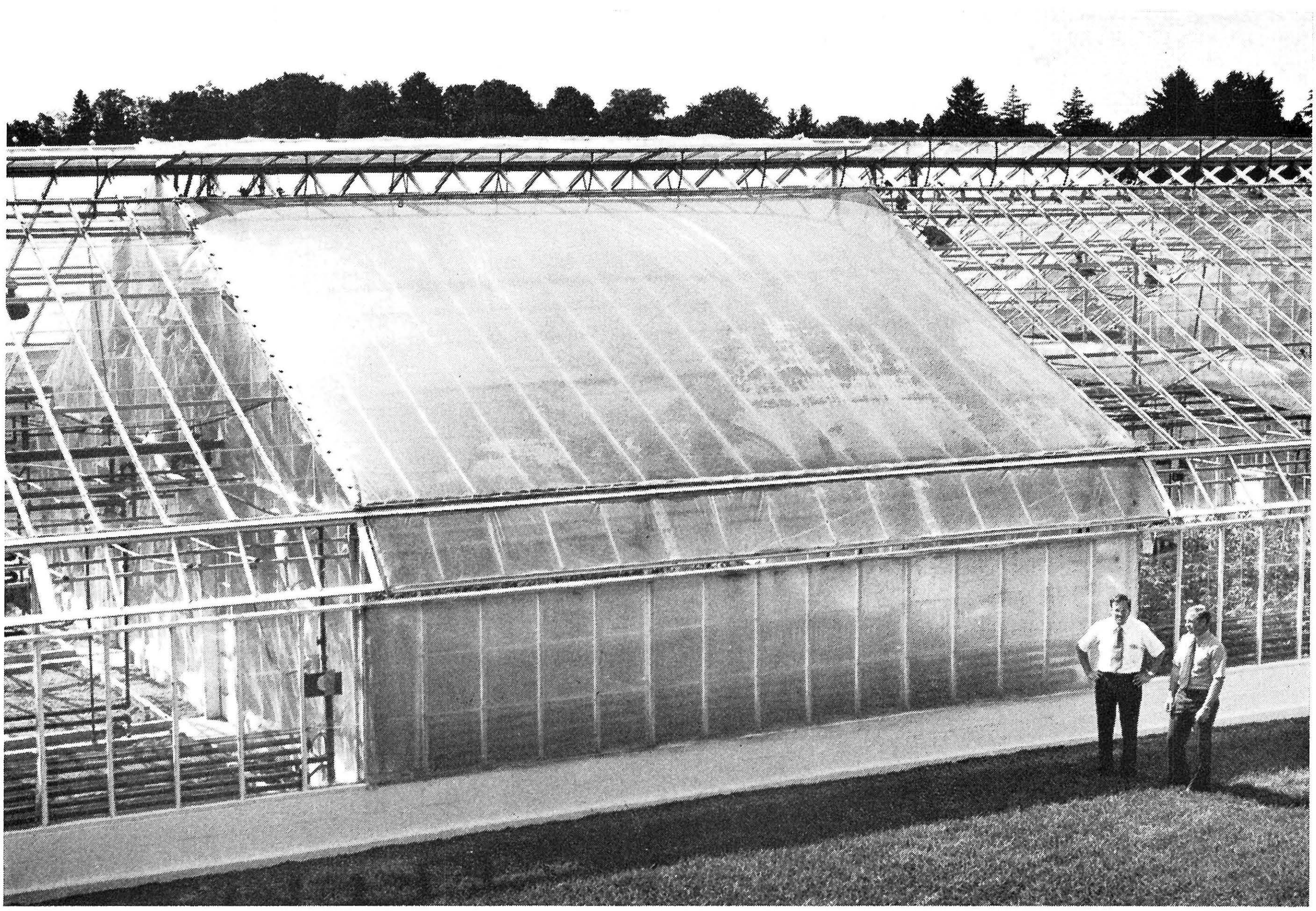

OHIO AGRICULTURAL RESEARCH AND DEVELOPMENT CENTER
U. S. 250 and Ohio 83 South
Wooster, Ohio

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ON THE COVER—Ted H. Short and William H. Bauerle, Departments of Agricultural Engineering and Horticulture, are shown in front of the experimental greenhouse used for energy conservation studies at the Ohio Agricultural Research and Development Center, Wooster.

AGDEX 731/257-286 1-77-8.5M

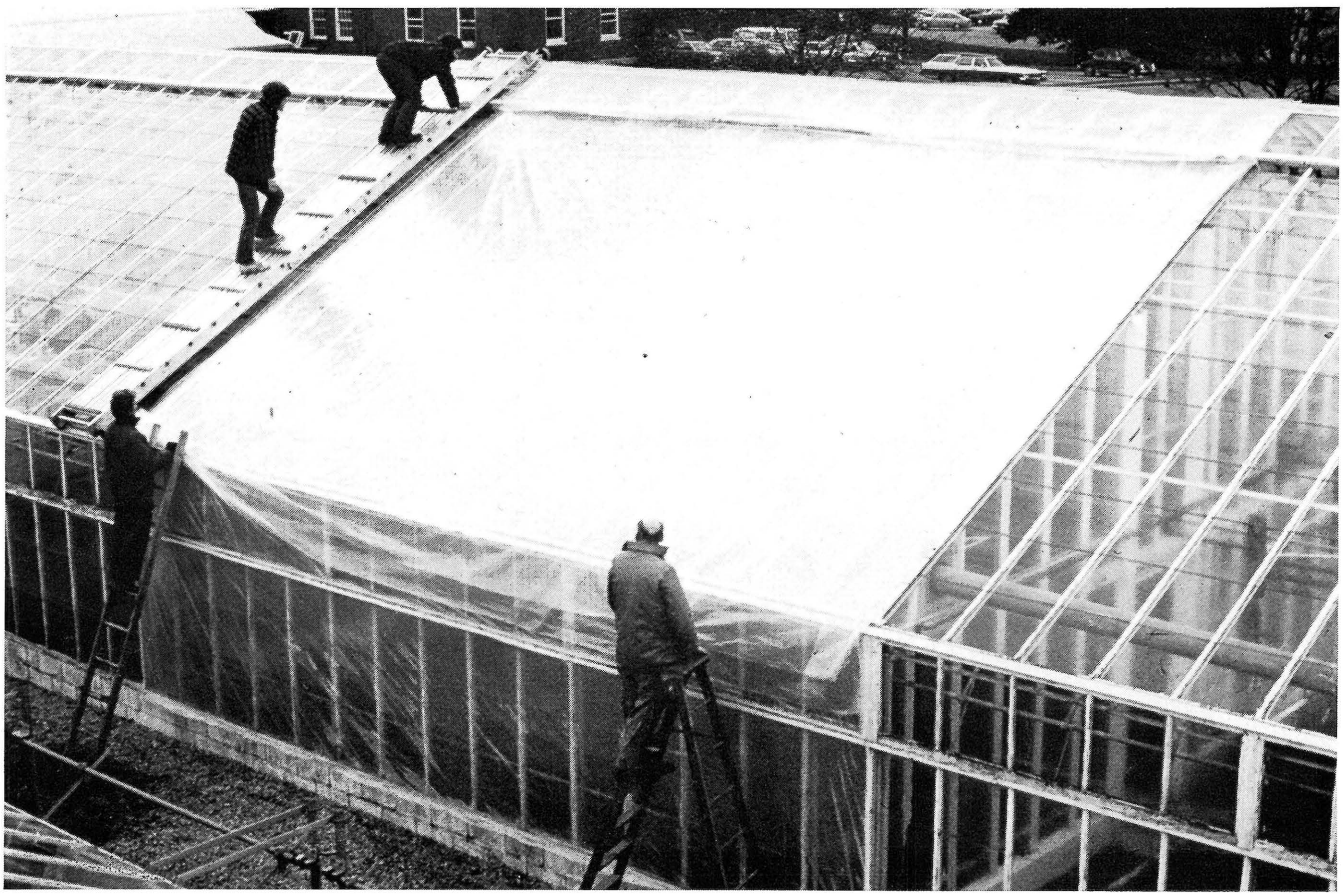

FIG. 1.—Two layers of Monsanto "602" plastic are installed on one compartment of an OARDC Department of Horticulture glass greenhouse for energy conservation research.

Conserving Heat in Glass Greenhouses with Surface-mounted Air-inflated Plastic[1]

W. L. BAUERLE and T. H. SHORT[2]

The increasing cost and reduced availability of clean-burning fossil fuel pose a threat to the future of the greenhouse industry. Therefore, research aimed at reducing energy consumption for heating greenhouses has been given high priority.

In November 1975, a double-layered, air-inflated plastic cover was placed over one of the horticultural glasshouse compartments at the Ohio Agricultural Research and Development Center, Wooster. The material was "602" greenhouse sheeting by Monsanto (Fig. 1). The vents on the experimental greenhouse were allowed to perform their normal ventilation function by covering them separately.

Steam flow meters and recorders were placed in both the plastic-covered glasshouse compartment and an identical conventional glasshouse compartment to measure the total amount of energy used in each. Solar radiometers were placed inside and outside of each compartment to measure sunlight accumulation. Wind measurements were recorded to determine the total miles of wind per day across the experimental compartments. Total yield and fruit quality data were recorded.

Measurements of energy requirements for each of the two compartments from December 1975 through March 1976 (the 4 coldest months of the year in Ohio) revealed that the double plastic cover reduced the total heat use by 57%.

Glass and structural members of the conventional glass greenhouse reduced the solar radiation by an average of 35%. An additional reduction of 18% was measured in the double plastic-covered glasshouse. The plastic cover, however, tended to diffuse the light more uniformly within the greenhouse and structural shading was less apparent.

The daytime relative humidity in the plastic-covered glasshouse was approximately 12% greater than in the conventional glasshouse during the winter months when the vents were closed. High levels of humidity tend to reduce plant stress and improve pollen viability on a spring tomato crop. No difference in disease incidence was observed.

The total number of fruit on each plant was similar for both compartments. However, fruit weight per plant was reduced in the plastic-covered house by 6.5% for W-R 25, 4.3% for M-R 13, and 10.3% for Hybrid O. (Hybrid O is not normally grown as a spring crop.)

The economic implications of these results have caused much grower interest in the double-cover system for glasshouses. A few growers have already tried the system and have encountered technical difficulties with installation. Other growers have successfully used this system for 2 years.

The following outline of procedures was developed to aid in proper installation and help growers anticipate problems which may occur. It should be recognized that the research was concerned strictly with energy use implications. Problems associated with greenhouse structural integrity during snow or wind loads have not been evaluated. In all cases, it is best to gain experience by starting with only one house or a portion of one house.

EQUIPMENT AND MATERIALS

Covering. It is very important to purchase plastic film which is ultraviolet light (UV)-resistant and manufactured especially for greenhouse use. Monsanto "602," a UV-resistant polyethylene greenhouse sheeting, is one material which is widely used and should last 2 years. Some rolls of repair tape should be purchased with the film.

If two separate sheets of plastic are used, a 4 mil thick sheet can be applied for the bottom layer and a 6 mil sheet can be used for the outer layer. If lay-flat tubing is used, a thickness of 6 mils is recommended.

Fasteners. Fastening devices for plastic (Fig. 2) are available from most plastic greenhouse manufacturers and suppliers.

Inflation. Double-layer plastic covers are usually inflated with a 1/30-hp. centrifugal blower with a 3-13/16-in. diameter x 1-7/8-in. wide wheel and a maximum output pressure of 1.0 in. of water column pressure. A "rule of thumb" is to order one blower for every 10,000 sq. ft. of greenhouse area. The blower should be mounted before covering is started.

[1]Mention of a trade name, product, or specific equipment does not constitute endorsement, guarantee, or warranty by the Ohio Agriculture Research and Development Center, nor does it imply approval to the exclusion of other products which may be suitable.

[2]William L. Bauerle is associate professor, Department of Horticulture, and Ted H. Short is associate professor, Department of Agricultural Engineering, Ohio Agricultural Research and Development Center, Wooster. Research was supported in part by the Monsanto Company, North 8th St. and Monroe Ave., Kenilworth, N. J., 07033.

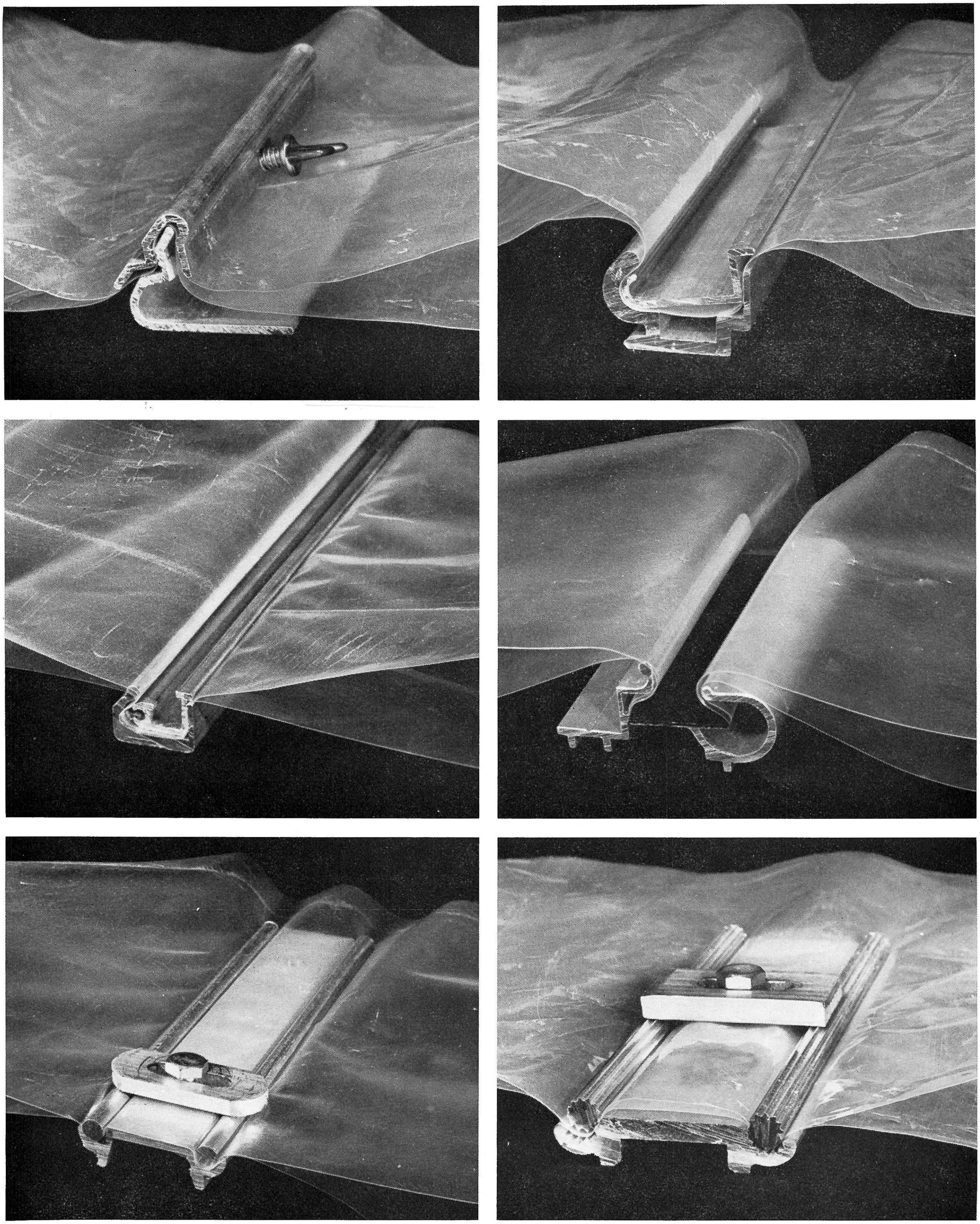

FIG. 2.—Six different types of fastening devices which are available from manufacturers and suppliers of plastic greenhouses.

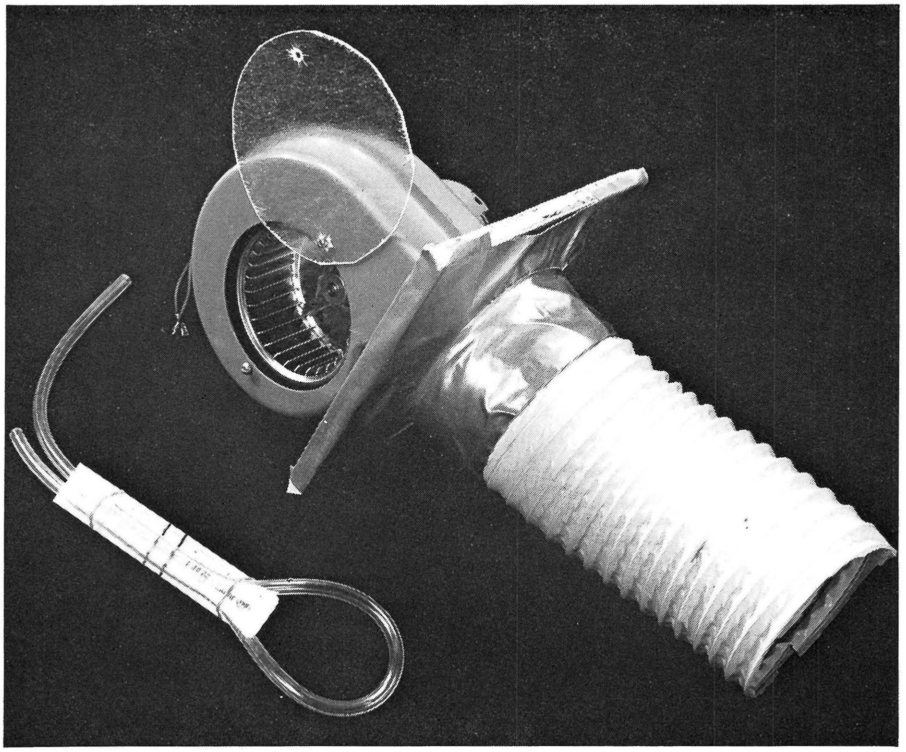

FIG. 3.—Inflation blower assembly with damper plate, attachment board, and 4-in. dryer duct in the outlet. At left is a homemade water manometer.

A damper plate should be made for the air inlet side of the blower (Fig. 3) so that the air pressure between the two sheets of plastic can be regulated. If possible, the air intake side of the blower should pull outside air to reduce condensation between the two layers of plastic. Any condensation on the plastic will reduce light transmission.

A 4-in. clothes dryer flexible duct tubing and 4-in. galvanized stove pipe can be used to connect the blower to the bottom plastic cover.

A pane of glass should be removed from the greenhouse roof and replaced with a piece of ⅜-in. marine plywood. The plywood is used to hold the inflation duct close to the bottom sheet of plastic. The plywood should be fastened to the sash bars and needs to be no more than 6-10 in. wide. A 4-in. hole drilled in the plywood will hold the galvanized pipe near the bottom layer of plastic.

Manometer. A manometer should be used to measure the air pressure between the two layers. This can be made with a 3-ft. piece of clear plastic tubing. Use enough water to fill a 12-in. section of the tubing. Loop about 8 in. of one end up to form a "U" and fasten to the sides of a ruler. This should give two 6-in. columns of water (Fig. 3). Cut a small hole in the plastic some distance from the blower and slide the long leader end of the tube through the hole. The distance between the top of the two columns of water is the water column air pressure between the plastic. Approximately 0.25 in. of water pressure should be maintained when the plastic is inflated.

PREPARING THE GREENHOUSE STRUCTURE

Step. 1. Remove all sharp protruding objects from the outside surface of the greenhouse to prevent puncturing or tearing of plastic during application.

Step 2. Obtain plastic securing devices (Fig. 2) to achieve uniform and secure fastening. It is very important that the securing devices be firmly fastened to the greenhouse.

Step 3. Sash bars must be firmly attached to gutter plate before securing devices are fastened to them. Where weak rafter members are anticipated, either repair the sash bars or attach the plastic securing device to the gutter.

Step 4. Attach plastic securing devices to the bottom of the sash bars and just below the vents if the vents are being used.

Step 5. When necessary, wash outside glass with glass cleaning compound or water and brush to insure better light transmission through glass.

Step 6. If top vents are not being used and the total length of the roof from gutter to gutter is less than 40 ft., attach securing devices at the gutters and cover the entire greenhouse with two single sheets of plastic.

Step 7. If the greenhouse is longer than available plastic, a transition fastener can be located at one of the sash bars. These same fasteners are often used at the end of the roof.

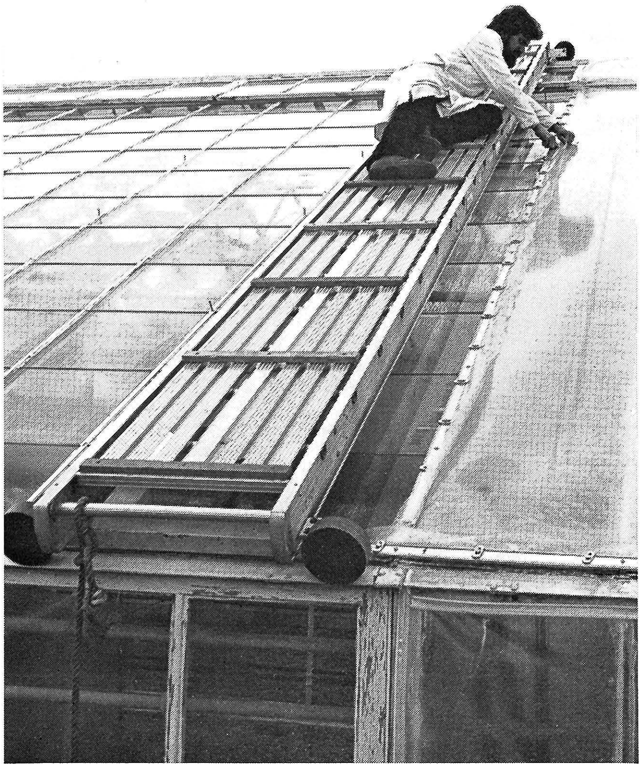

FIG. 4.—The mobile scaffold (above) was made by modifying an ordinary aluminum ladder (see Fig. 5).

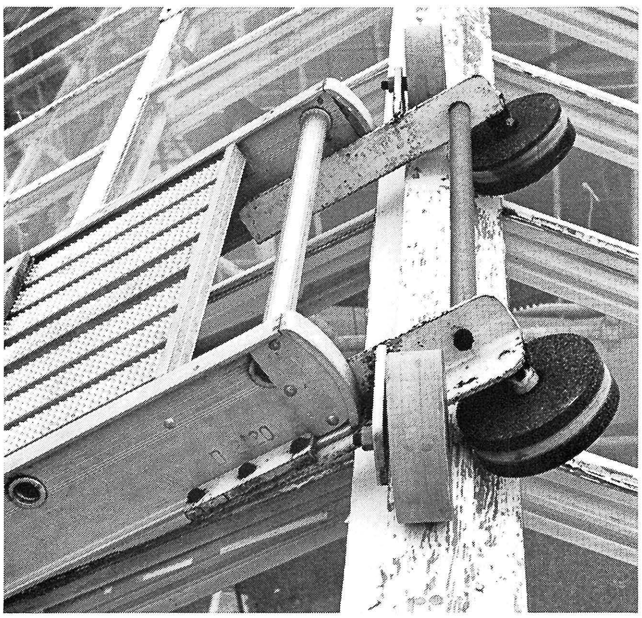

FIG. 5.—Closeup of roller arrangement at the top of the mobile scaffold.

INSTALLATION

Step 1. Winds should be at a minmum when the plastic is installed on the greenhouse.

Step 2. After securing the plastic fastening devices to the rafters and installing the blower attachments, the plastic is rolled out over the greenhouse superstructure. A portable scaffold (Fig. 4 and 5) can be very helpful during this process.

Step 3. The plastic film should be pulled, but not stretched, to lay freely over the structure.

Step 4. The plastic film can then be fastened with the securing devices. Excessive pulling and stretching of the plastic before or during securing should be avoided since all wrinkles will disappear after inflation. There is also less tearing stress and stretching at the fastener if a loose sheet of plastic is inflated.

Step 5. Once both sheets of plastic are secured, the blower air duct can be attached to the bottom layer of plastic. Carefully make a circle on the bottom sheet of plastic through the 4-in. hole in the plywood. Cut this circular area into eight pie-shaped segments which are still attached at the circumference. Small tape loops on the thumb and forefinger are helpful in holding the bottom sheet away from the top sheet for the initial cut. Working around and above the plywood, temporarily fold back these segments and tape them to the underneath side of the lower plastic sheet. Inset the fan duct through the plywood and just through the new hole in the lower sheet. Release the tape holding the pie-shaped segments and form them around the fan duct. Tape the pie-shaped segments securely to the fan duct with two or three loops of tape. Pull the duct down through the plywood until the tape, plastic, and duct make a snug fit with the plywood hole. Once this is accomplished, the plastic film is ready to be inflated.

Step 6. Straps or tiedowns across the top of the plastic sheets are not recommended since they are more likely to tear the plastic than hold it in place.

Step 7. Sections of plastic that are not attached directly to a blower can be connected to inflated sections by making small slits and inserting short lengths of garden hose.

OPERATION AND MAINTENANCE

Step 1. Begin inflation as soon as a section of plastic film is secured around the edges. It will take more than an hour to inflate larger sections.

Step 2. Cut a small hole in the bottom sheet of plastic to insert the manometer tube. This hole can be closed later with tape. Do not become alarmed at excessive billowing or separation of the plastic as long as the pressure is less than 0.5-in. water pressure. The recommended operation pressure is 0.25-in. water pressure and the recommended blower will not normally produce more than 1.0-in. water pressure.

Step 3. If the pressure is above 0.5-in. of water pressure, the damper on the blower should be closed slightly. If the high pressure persists, cut a small hole in one of the sheets some distance from the blower.

Step 4. Maintain a supply of tape to repair any holes or tears that may occur during installation.

OBSERVATIONS

The plastic should remain pressurized at all times. Normal operating pressure will keep the plastic from having wind ripples and make it feel soft to a gentle push. Many growers installing double plastic for the first time become alarmed at billowing after inflation. Considerable billowing is normal and effectively allows the outer cover to adjust to variable wind and internal pressure loadings. If allowed to remain deflated for a number of days, the wind-whipped plastic will slowly begin to tear near the fasteners.

The effect of double covers on paint peeling has not been fully assessed. However, little or no peeling has been observed with air-inflated double covers. The inside cover is pressed so securely against the bars that it may actually protect the paint. Most grower experiences with plastic covers causing paint peeling have been associated with single, uninflated covers on sidewalls. Uninflated plastic covers typically cause paint peeling by collecting moisture and hammering the paint on windy days.

Heavy snow loading on gutter-connected houses may be a major problem. Generally, an air-inflated plastic cover tends to distribute snow loads much better than glass. Normal snow and ice accumulations melt off slowly as long as the cover remains inflated and effectively insulated. If the cover is temporarily deflated the melting rate is greatly increased. Large snow loads tend to naturally deflate the cover in the heaviest loaded areas. The probability of glass breakage under these circumstances is not known. Neither is it known whether glass breakage would occur under the same circumstances without the plastic. It is most likely that the plastic will still maintain the integrity of the roof even if some glass does break.

Obviously there are risks which must be taken in applying double plastic to glass greenhouses. The potential heat savings of 57% indicated by OARDC research makes the risks economically worth consideration and in some cases necessary. It is most important that growers first cover only a small area to get experience. Growers should also be sure to contact their insurance company before proceeding. The Ohio Agricultural Research and Development Center can only verify the energy and crop responses under the glasshouse and double-plastic covered glasshouse conditions.

There have not been any engineering analyses of the structural responses to the double-plastic cover system and OARDC cannot be held responsible for any failures.

To date, no serious failures have occurred as a result of double plastic over glass greenhouses located in heavy snowfall areas. It is anticipated that further grower trials and observations will be made known to the industry for future use.

The State Is the Campus for Agricultural Research and Development

Ohio's major soil types and climatic conditions are represented at the Research Center's 12 locations.

Research is conducted by 15 departments on more than 7000 acres at Center headquarters in Wooster, seven branches, Green Springs Crops Research Unit, Pomerene Forest Laboratory, North Appalachian Experimental Watershed, and The Ohio State University.

Center Headquarters, Wooster, Wayne County: 1953 acres

Eastern Ohio Resource Development Center, Caldwell, Noble County: 2053 acres

Green Springs Crops Research Unit, Green Springs, Sandusky County: 26 acres

Jackson Branch, Jackson, Jackson County: 502 acres

Mahoning County Farm, Canfield: 275 acres

Muck Crops Branch, Willard, Huron County: 15 acres

North Appalachian Experimental Watershed, Coshocton, Coshocton County: 1047 acres (Cooperative with Agricultural Research Service, U. S. Dept. of Agriculture)

Northwestern Branch, Hoytville, Wood County: 247 acres

Pomerene Forest Laboratory, Coshocton County: 227 acres

Southern Branch, Ripley, Brown County: 275 acres

Western Branch, South Charleston, Clark County: 428 acres